CLAIMS

1. A vibration sensing device comprising:
a hollow flextensional body having a cross section that has a major and a minor axis, said flextensional body being operable to deform in response to received vibrational energy and thereby produce a variation in a predetermined property exhibited by said body in the direction of one of said major or minor axis, said flextensional body being shaped such that said variation in said predetermined property is amplified in the direction of the other of said major or minor axis; and
a sensor coupled with the flextensional body and operable to detect the amplified variation indicative of received vibrational energy.

2. A vibration sensing device according to claim 1, wherein said predetermined property comprises force, vibrational energy received along said minor axis causing deformation of said flextensional body, with a force acting along said minor axis and an amplified force acting along said major axis, said sensor being coupled to said flextensional body along said major axis to detect the amplified force.

3. A vibration sensing device according to claim 1, wherein said predetermined property comprises displacement, vibrational energy received along said major axis causing displacement of said flextensional body along said major axis and an amplified displacement along said minor axis, said sensor being coupled to said flextensional body along said minor axis to detect the amplified displacement.

4. A vibration sensing device according to any of the preceding claims, said vibration sensing device further comprising an outer housing for housing said vibration sensing device.

5. A vibration sensing device according to any of the preceding claims, said vibration sensing device further comprising a mass mounted on said flextensional body.

6. A vibration sensing device according to claim 5 when dependent on claim 2, wherein said minor axis has a first and a second end, said mass being mounted to said flextensional body in the proximity of said first end of said minor axis.

7. A vibration sensing device according to claim 6 when dependent on claim 4, wherein said flextensional body is mounted to said outer housing via mounting means, said mounting means connecting a portion of said flextensional body in the proximity of said second end of said minor axis to said housing.

8. A vibration sensing device according to claim 5 when dependent on claim 3, said major axis having a first and a second end, and said mass is mounted to said flextensional body in the proximity of said first end of said major axis.

9. A vibration sensing device according to claim 8 when dependent on claim 4, wherein said flextensional body is mounted to said outer housing via mounting means, said mounting means connecting a portion of said flextensional body in the proximity of said second end of said major axis to said housing.

10 A vibration sensing device according to any of the preceding claims wherein said flextensional body is formed of metal.

11. A vibration sensing device according to any of the preceding claims wherein said flextensional body comprises a tube with an elliptical cross-section.

12. A vibration sensing device according to any preceding claim, wherein said mass is mounted within said hollow flextensional body.

13. A vibration sensing device according to any preceding claim, wherein said flextensional body comprises an outer wall, said outer wall having a substantially uniform thickness.

14. A vibration sensing device according to any preceding claim, wherein said major axis of said flextensional body is between 10 mm and 30mm long.

15. A vibration sensing device according to claim 14, wherein said major axis is of said flextensional body is substantially 22mm long.

16. A vibration sensing device according to any preceding claim, wherein said minor axis of said flextensional body is between 5mm and 20mm long.

17. A vibration sensing device according to claim 16, wherein said minor axis of said flextensional body is substantially 11mm long.

18. A vibration sensing device according to any of the preceding claims, wherein said vibration sensing device comprises an accelerometer.

19. A vibration sensing device according to any preceding claim, wherein said sensor comprises a strain sensor

20. A vibration sensing device according to any preceding claim, wherein said sensor comprises an optical fibre coupled to said flextensional body such that deformation of said flextensional body produces a strain in said optical fibre which imposes a variation in at least one predetermined property of an optical signal transmitted through said optical fibre, said optical fibre being arranged such that at least one end is accessible for optical coupling to an optical device comprising a detector for detecting said changes in said at least one predetermined property of said transmitted optical signal.

21. A vibration sensing device according to claim 20, wherein said optical fibre is coupled under stress to said flextensional body.

22. A vibration sensing device according to claim 20 or 21 when dependent on claim 3, said vibration sensing device comprising blocks mounted on the outer surface of said flextensional body at either end of said minor axis, said optical fibre sensor comprising an optical fibre coil, said optical fibre coil being coupled to said flextensional body by being wound around said blocks.

23. A vibration sensing device according to claim 20 or 21 when dependent on claim 2, wherein said vibration sensing device comprises blocks mounted on the outer surface of said flextensioal body at either end of said major axis, said optical fibre sensor being coupled to said flextensional body by being wound around said blocks.

24. A vibration sensing device according to any of claims 22 or 23 wherein said blocks are formed of metal.

25. A vibration sensing device according to any one of claims 20 to 24, wherein said optical fibre is coupled to said flextensional body such that both ends of said optical fibre are accessible for optical coupling to further optical devices.

26. A vibration sensing package, comprising three vibration sensing devices according to any of the preceding claims, each of said three vibration sensing devices having a sensor coupled along an axis of said sensing device, said three vibration sensing devices being mounted such that said axes along which respective sensors are coupled are arranged orthogonally to one another.

27. A vibration sensing package according to claim 26, said package further comprising a hydrophone.

28. A vibration sensing system, comprising:

a first plurality of vibration sensing devices according to any one of claims 20 to 25;

an electromagnetic radiation source and an electromagnetic radiation detector;
said optical fibres of said first plurality of vibration sensing devices being arranged in optical communication with each other and with said electromagnetic radiation source and detector;
said electromagnetic radiation source being operable to transmit an optical signal into said optical fibres of said plurality of vibration sensing devices; and
said electromagnetic radiation detector being arranged to receive electromagnetic radiation output from said plurality of vibration sensing devices and to detect a variation in at least one predetermined property of said output optical signal.

29. A vibration sensing system according to claim 28, where said first plurality of vibration sensing devices are arranged optically in series.

30. A vibration sensing system according to any one of claim 28 or 29, said sensing system further comprising a plurality of partial radiation reflectors, said plurality of partial radiation reflectors being arranged before and after each of said plurality of vibration sensing devices; wherein
said electromagnetic radiation source is operable to transmit a plurality of pulses into said first plurality of vibration sensing devices such that a pulse of radiation that is reflected back through one vibration sensing device by a reflector immediately after said vibration sensing device reaches said electromagnetic radiation detector at the same time as, and interacts with, a subsequent pulse reflected by a reflector immediately before said one vibration sensing device;
said variations in said at least one predetermined property of said optical signal detected by said electromagnetic radiation detector being variations in phase.

31. A vibration sensing system according to claim 30, further comprising a signal processor including a time division demultiplexer, said signal processor being operable to process signals produced by said electromagnetic detector in response to said variations in phase and to isolate signals from individual vibration sensing devices using said time division demultiplexer.

32. A vibration sensing system according to any one of claims 29 to 31, further comprising:

a second plurality of vibration sensing devices arranged optically in series with each other, said second plurality of vibration sensing devices being arranged optically in parallel with said first plurality of vibration sensing devices; and

a first and second wavelength multiplex/demultiplex unit operable to isolate a single frequency; wherein

said electromagnetic source is operable to produce pulses of radiation at first and second frequencies and said first and second wavelength multiplex/demultiplex units are arranged such that pulses of said first frequency are transmitted from said source to said first plurality of vibration sensing devices and pulses of said second frequency are transmitted from said source to said second plurality of vibration sensing devices.

33. A vibration sensing system according to claim 32, further comprising

at least one further plurality of vibration sensing devices and at least one further wavelength multiplex/demultiplex unit, said at least one further plurality of vibration sensing devices being arranged optically in parallel with said first and said second plurality of vibration sensing devices; wherein

said electromagnetic source is operable to produce pulses of radiation at first, second and at least one further frequency and said at least one further multiplex/demultiplex unit is arranged such that pulses of said at least one further frequency are transmitted from said source to said at least one further plurality of vibration sensing devices.

34. A vibration sensing system according to claim 31 wherein said first plurality of vibration sensing devices are arranged optically in parallel.

35 A vibration sensing system according to any one of claims 28 to 34, comprising a plurality of vibration sensing packages according to claims 26 or 27 when dependent on any one of claims 20 to 25.

36. A method of detecting vibrations comprising:

coupling a sensor to a hollow flextensional body having a cross section that has a major and a minor axis, said flextensional body being operable to deform in response to received vibrational energy and thereby produce a variation in a predetermined property exhibited by said flextensional body in the direction of one of said major or minor axis, said flextensional body being shaped such that said variation in a predetermined property is amplified in the direction of the other of said major or minor axis; and

placing said flextensional body in an environment where vibrational energy is to be detected; and

detecting the amplified variation indicative of received vibrational energy with said sensor.

37. A method of detecting vibrations according to claim 36, wherein said predetermined property comprises force, said flextensional body being placed in an environment to receive vibrational energy along its minor axis, which causes deformation of said flextensional body with a force acting along the minor axis and an amplified force acting along the major axis, said sensor being coupled to the flextensional body along the major axis to detect the amplified force.

38. A method of detecting vibrations according to claim 36, wherein said predetermined property comprises displacement, said flextensional body being placed in an environment to receive vibrational energy along its major axis which causes displacement of said flextensional body along said major axis and an amplified displacement along said minor axis, said sensor being coupled to said flextensional body along said minor axis to detect the amplified displacement.

39. A method of detecting vibrations further comprising mounting a mass to said flextensional body.

40. A method of detecting vibrations according to claim 37 wherein mass is mounted to a face of said flextensional body in the proximity of one end of said minor axis, vibrations parallel to the minor axis being detected

41. A method of detecting vibrations according to claim 38, and said mass is mounted to a face of said flextensional body in the proximity of one end of said major axis, vibrations parallel to the major axis being detected.

42. A method of detecting vibrations according to any one of claims 36 to 41, further comprising mounting a plurality of said flextensional bodies in an array and placing said array in an environment where vibrations are to be detected.

43. A method of detecting vibrations according to claim 37 or 38, comprising mounting three of said flextensional bodies together in a package such that said axes along which each respective sensor is coupled are arranged orthogonally to one another and placing said package in an environment where vibrations are to be detected.

44. A method of manufacturing a vibration sensing device according to any one of claims 20 to 25 comprising the steps of

(i) mounting blocks on an outside surface of said flextensional body at either end of said minor or said major axis:

(ii) holding said flextensional body within chucks adapted to pass around and hold the outer edges of said blocks within an optical coil winding apparatus;

(iii) passing an optical fibre through a reservoir of resin, such that a layer of resin coats said optical fibre, said optical fibre exiting said reservoir of resin via a needle, said needle being operable to position said optical fibre above said flextensional body held within said chucks and being arranged to allow a suitable amount of resin to coat said fibre;

(iv) rotating said flextensional body such that said optical fibre is wound about said blocks mounted at either end of an axis of said flextensional body to form a coil of optical fibre wound around said axis, said coil being attached to said blocks by said resin and at least one end of said optical fibre being accessible for connection to external optical components.

45. A method of manufacturing a vibration sensing device according to claim 44, wherein step (iv) is performed such that both ends of said optical fibre are accessible for connection to external optical components.

46. A method of manufacturing a vibration sensing device according to claim 44 or 45, wherein said step (iv) of winding said optical fibre is performed such that coil is wound under tension.

47. A method of manufacturing a vibration sensing device according to any one of claims 44 to 46, comprising a further step of continuing to rotate said flextensional body after winding said coil until said resin has set.

48. A vibration sensing device, substantially as hereinbefore described with reference to the accompanying drawings.

49. A vibration sensing package, substantially as hereinbefore described with reference to the accompanying drawings.

50. A vibration sensing system, substantially as hereinbefore described with reference to the accompanying drawings.

51. A method of manufacturing a vibration sensing device, substantially as hereinbefore described with reference to the accompanying drawings.